SBOS333B – JULY 2005 – REVISED OCTOBER 2005

# Precision, Gain of 0.2 Level Translation DIFFERENCE AMPLIFIER

## FEATURES

- GAIN OF 0.2 TO INTERFACE ±10V SIGNALS TO SINGLE-SUPPLY ADCs
- GAIN ACCURACY: ±0.024% (max)
- WIDE BANDWIDTH: 1.5MHz
- HIGH SLEW RATE: 15V/μs
- LOW OFFSET VOLTAGE: ±100μV
- LOW OFFSET DRIFT: ±1.5μV/°C
- SINGLE-SUPPLY OPERATION DOWN TO 1.8V

## APPLICATIONS

- INDUSTRIAL PROCESS CONTROLS
- INSTRUMENTATION
- DIFFERENTIAL TO SINGLE-ENDED CONVERSION
- AUDIO LINE RECEIVERS

## DESCRIPTION

The INA159 is a high slew rate, G = 1/5 difference amplifier consisting of a precision op amp with a precision resistor network. The gain of 1/5 makes the INA159 useful to couple ±10V signals to single-supply analog-to-digital converters (ADCs), particularly those operating on a single +5V supply. The on-chip resistors are laser-trimmed for accurate gain and high common-mode rejection. Excellent temperature coefficient of resistance (TCR) tracking of the resistors maintains gain accuracy and common-mode rejection over temperature. The input common-mode voltage range extends beyond the positive and negative supply rails. It operates on a total of +1.8V to +5.5V single or split supplies. The INA159 reference input uses two resistors for easy mid-supply or reference biasing.

The difference amplifier is the foundation of many commonly-used circuits. The INA159 provides this circuit function without using an expensive external precision resistor network. The INA159 is available in an MSOP-8 surface-mount package and is specified for operation over the extended industrial temperature range, –40°C to +125°C.

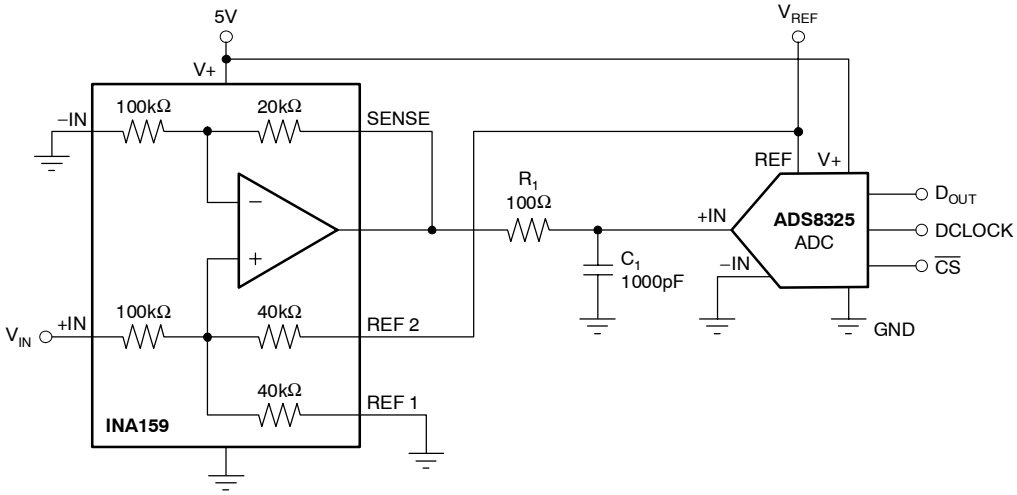


**Figure 1. Typical Application**

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## ABSOLUTE MAXIMUM RATINGS(1)

| | |
|---|---|
| Supply Voltage | +5.5V |
| Signal Input Terminals (–IN and +IN), Voltage | ±30V |
| Reference (REF 1 and REF2) and Sense Pins | |
| Current | ±10mA |
| Voltage | (V–) – 0.5V to (V+) + 0.5V |
| Output Short Circuit | Continuous |
| Operating Temperature | –40°C to +150°C |
| Storage Temperature | –65°C to +150°C |
| Junction Temperature | +150°C |
| ESD Rating | |
| Human Body Model | 4000V |
| Charged Device Model | 1000V |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## ORDERING INFORMATION(1)

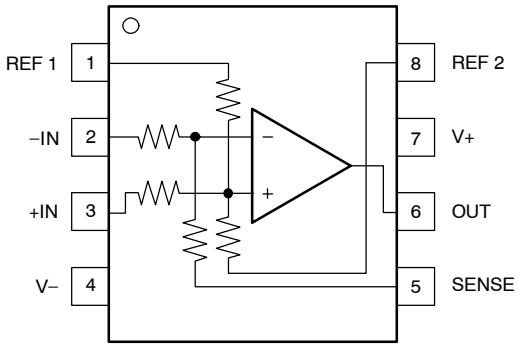
| PRODUCT | PACKAGE-LEAD | PACKAGE DESIGNATOR | PACKAGE MARKING |
|---|---|---|---|
| INA159 | MSOP-8 | DGK | CJB |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

## PIN CONFIGURATIONS

**TOP VIEW** **MSOP**

**INA159**



## ELECTRICAL CHARACTERISTICS: $V_S$ = +5V

**Boldface** limits apply over the specified temperature range, **$T_A$ = –40°C to +125°C.**

At $T_A$ = +25°C, $R_L$ = 10kΩ connected to $V_S$/2, REF pin 1 connected to ground, and REF pin 2 connected to $V_{REF}$ = 5V, unless otherwise noted.

| PARAMETER | | CONDITIONS | INA159 MIN | INA159 TYP | INA159 MAX | UNIT |
|---|---|---|---|---|---|---|
| **OFFSET VOLTAGE**(1) | | RTO | | | | |
| Initial (1) | $V_{OS}$ | $V_S$ = ±2.5V, Reference and Input Pins Grounded | | ±100 | ±500 | µV |
| **vs Temperature** | | | | **±1.5** | | **µV/°C** |
| vs Power Supply | PSRR | $V_S$ = ±0.9V to ±2.75V | | ±20 | ±100 | µV/V |
| Reference Divider Accuracy(2) | | | | ±0.002 | ±0.024 | % |
| **over Temperature** | | | | **±0.002** | | **%** |
| **INPUT IMPEDANCE**(3) | | | | | | |
| Differential | | | | 240 | | kΩ |
| Common-Mode | | | | 60 | | kΩ |
| **INPUT VOLTAGE RANGE** | | RTI | | | | |
| Common-Mode Voltage Range | $V_{CM}$ | | | | | |
| Positive | | | | 17.5 | | V |
| Negative | | | | –12.5 | | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = –10V to +10V, $R_S$ = 0Ω | 80 | 96 | | dB |
| **over Temperature** | | | | **94** | | **dB** |
| **OUTPUT VOLTAGE NOISE**(4) | | RTO | | | | |
| f = 0.1Hz to 10Hz | | | | 10 | | $\mu V_{PP}$ |
| f = 10kHz | | | | 30 | | $nV/\sqrt{Hz}$ |
| **GAIN** | | $V_{REF2}$ = 4.096V, $R_L$ Connected to GND, $(V_{IN+}) - (V_{IN-})$ = –10V to +10V, $V_{CM}$ = 0V | | | | |
| Initial | G | | | 0.2 | | V/V |
| Error | | | | ±0.005 | ±0.024 | % |
| **vs Temperature** | | | | **±1** | | **ppm/°C** |
| Nonlinearity | | | | ±0.0002 | | % of FS |
| **OUTPUT** | | | | | | |
| Voltage, Positive | | $V_{REF2}$ = 4.096V, $R_L$ Connected to GND | (V+) – 0.1 | (V+) – 0.02 | | V |
| Voltage, Negative | | $V_{REF2}$ = 4.096V, $R_L$ Connected to GND | (V–) + 0.048 | (V–) + 0.01 | | V |
| Current Limit, Continuous to Common | | | | ±60 | | mA |
| Capacitive Load | | | | See Typical Characteristic | | pF |
| Open-Loop Output Impedance | $R_O$ | f = 1MHz, $I_O$ = 0 | | 110 | | Ω |
| **FREQUENCY RESPONSE** | | | | | | |
| Small-Signal Bandwidth | | –3dB | | 1.5 | | MHz |
| Slew Rate | SR | | | 15 | | V/µs |
| Settling Time, 0.01% | $t_S$ | 4V Output Step, $C_L$ = 100pF | | 1 | | µs |
| Overload Recovery Time | | 50% Overdrive | | 250 | | ns |
| **POWER SUPPLY** | | | | | | |
| Specified Voltage Range | $V_S$ | | | +5 | | V |
| Operating Voltage Range | | | +1.8 | | +5.5 | V |
| Quiescent Current | $I_Q$ | $I_O$ = 0mA, $V_S$ = ±2.5V, Reference and Input Pins Grounded | | 1.1 | 1.5 | mA |
| **TEMPERATURE RANGE** | | | | | | |
| Specified Range | | | –40 | | +125 | °C |
| Operating Range | | | –40 | | +150 | °C |
| Storage Range | | | –65 | | +150 | °C |
| Thermal Resistance | $\theta_{JA}$ | | | | | |
| MSOP-8 | | Surface-Mount | | 150 | | °C/W |

(1) Includes effects of amplifier input bias and offset currents.
(2) Reference divider accuracy specifies the match between the reference divider resistors using the configuration in Figure 2.
(3) Internal resistors are ratio matched but have ±20% absolute value.
(4) Includes effects of amplifier input current noise and thermal noise contribution of resistor network.

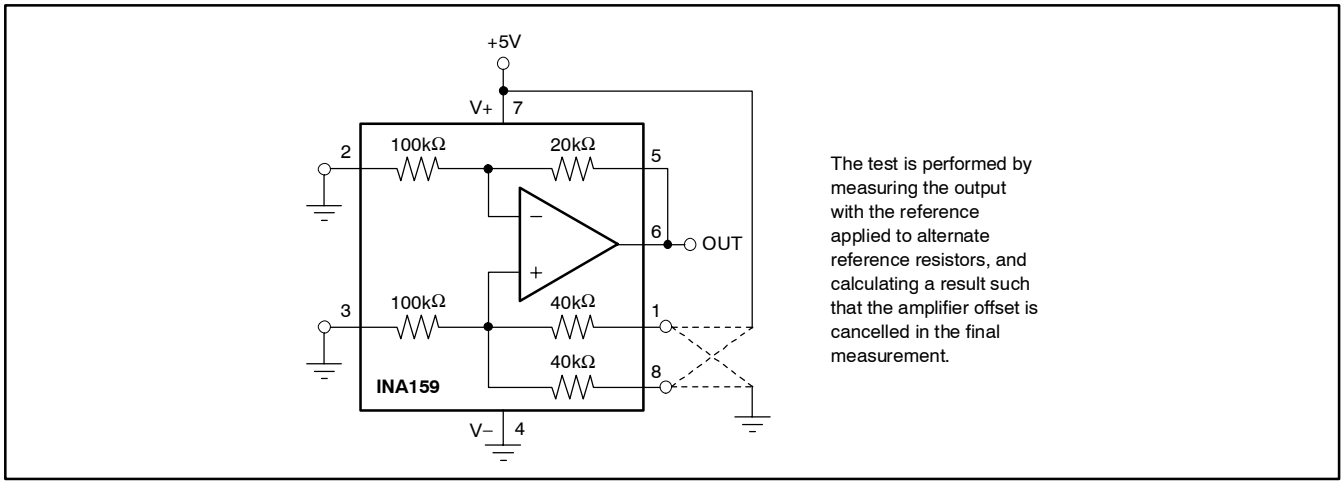
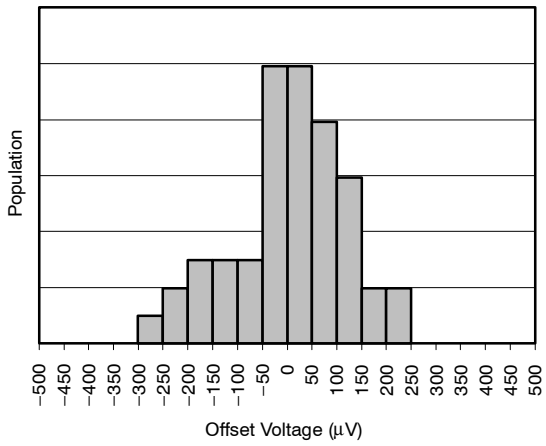



**Figure 2. Test Circuit for Reference Divider Accuracy**

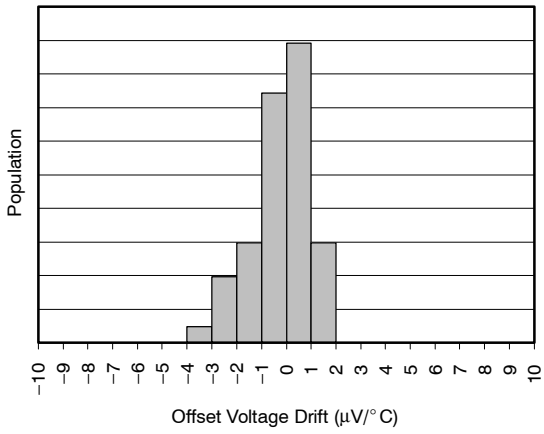
## TYPICAL CHARACTERISTICS

At $T_A$ = +25°C, $R_L$ = 10kΩ connected to $V_S$/2, REF pin 1 connected to ground, and REF pin 2 connected to $V_{REF}$ = 5V, unless otherwise noted.

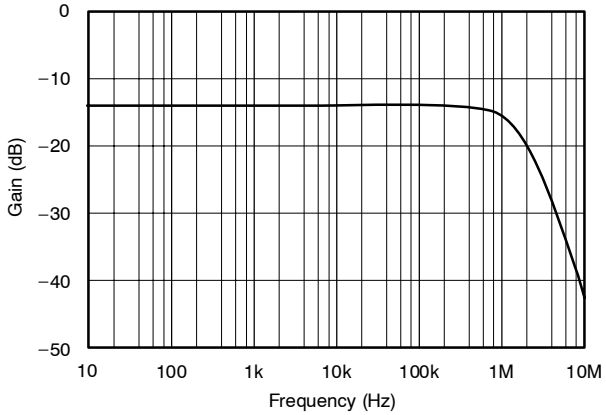
OFFSET VOLTAGE PRODUCTION DISTRIBUTION



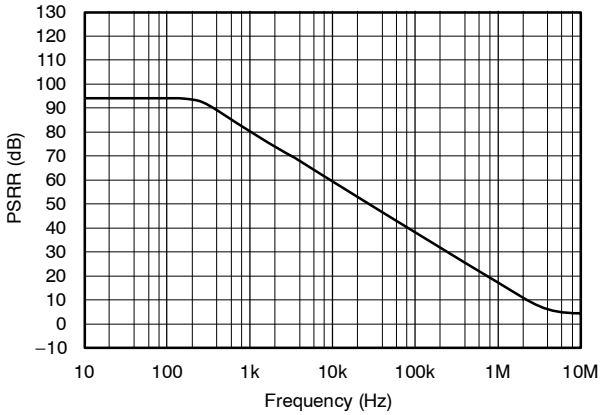

OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION




GAIN vs FREQUENCY



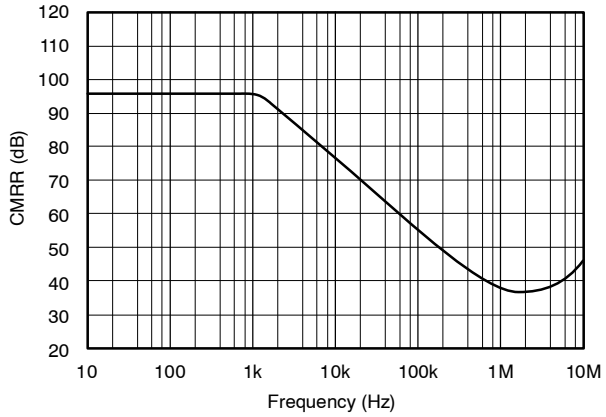

POWER−SUPPLY REJECTION RATIO vs FREQUENCY



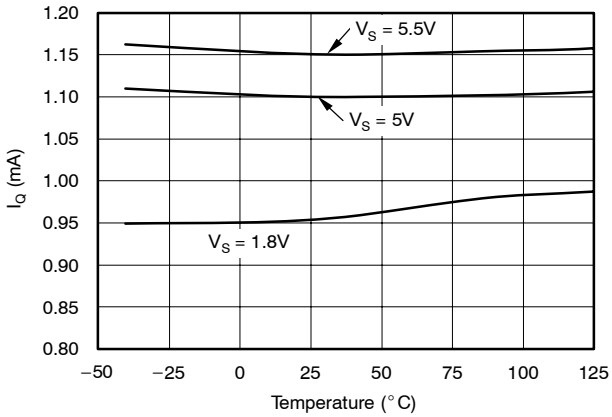
## TYPICAL CHARACTERISTICS (continued)

At $T_A$ = +25°C, $R_L$ = 10kΩ connected to $V_S$/2, REF pin 1 connected to ground, and REF pin 2 connected to $V_{REF}$ = 5V, unless otherwise noted.

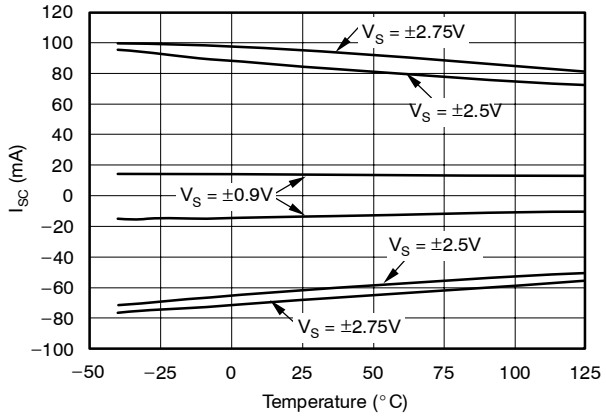
COMMON–MODE REJECTION RATIO vs FREQUENCY



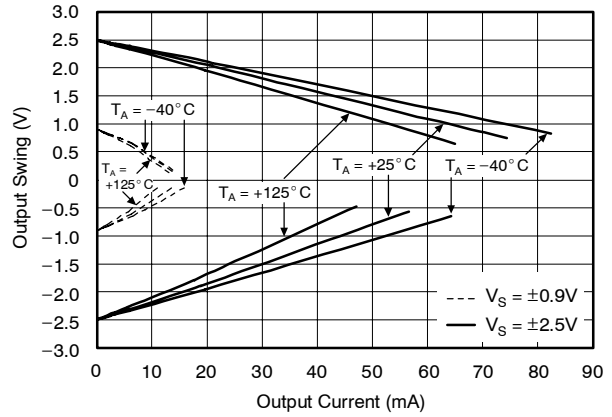

QUIESCENT CURRENT vs TEMPERATURE



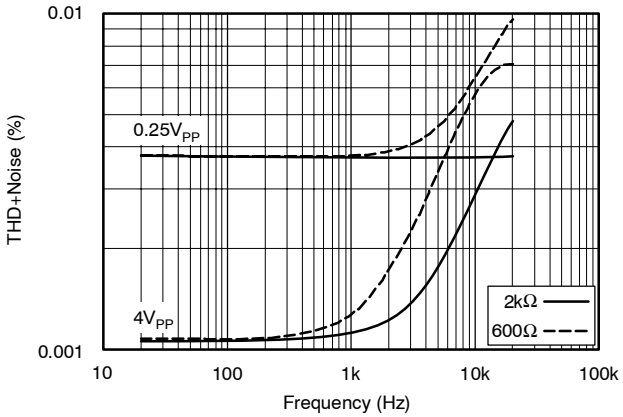

SHORT–CIRCUIT CURRENT vs TEMPERATURE



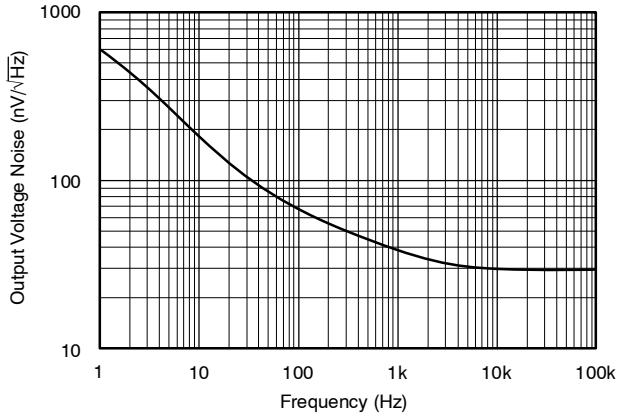

OUTPUT VOLTAGE SWING vs OUTPUT CURRENT




TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



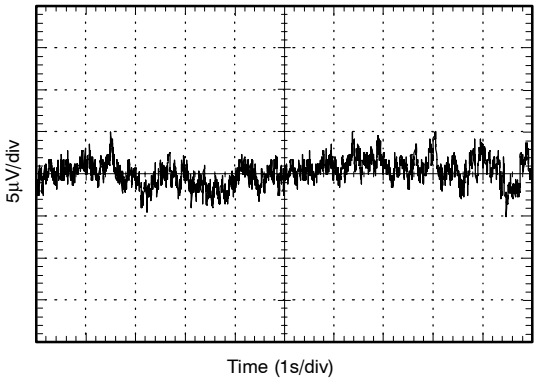

OUTPUT VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY



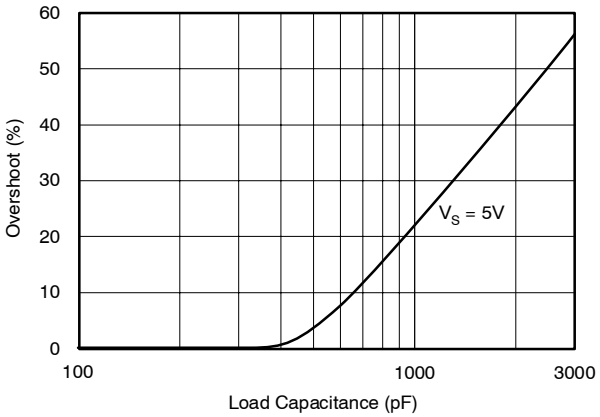
## TYPICAL CHARACTERISTICS (continued)

At $T_A$ = +25°C, $R_L$ = 10kΩ connected to $V_S$/2, REF pin 1 connected to ground, and REF pin 2 connected to $V_{REF}$ = 5V, unless otherwise noted.

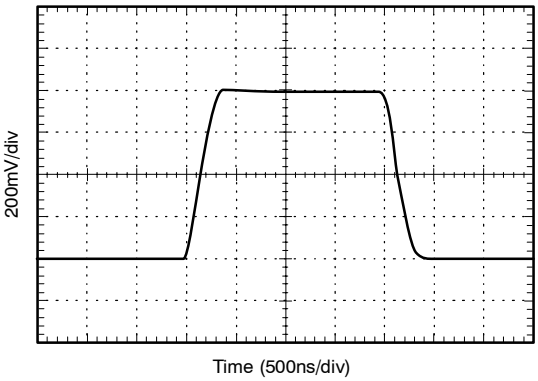
0.1Hz TO 10Hz NOISE



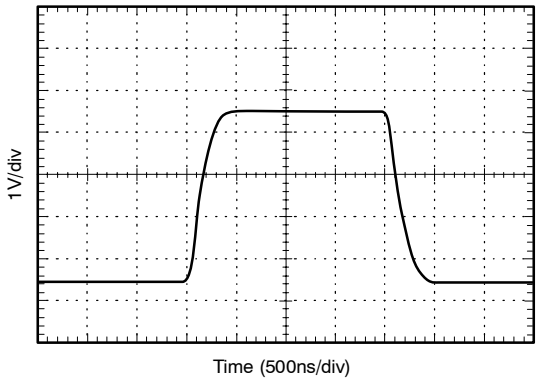

SMALL–SIGNAL OVERSHOOT vs LOAD CAPACITANCE



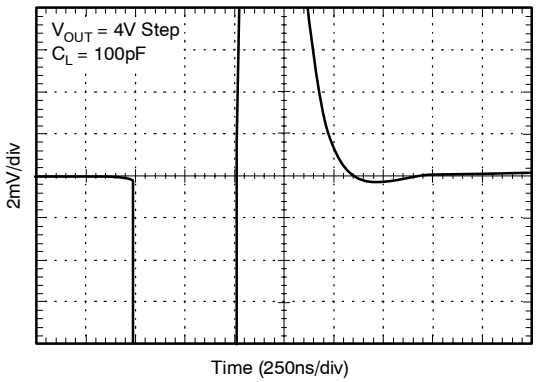

SMALL–SIGNAL STEP RESPONSE




LARGE–SIGNAL STEP RESPONSE




SETTLING TIME



# APPLICATION INFORMATION

The internal op amp of the INA159 has a rail-to-rail common-mode voltage capability at its inputs. A rail-to-rail op amp allows the use of ±10V inputs into a circuit biased to 1/2 of a 5V reference (2.5V quiescent output). The inputs to the op amp will swing from approximately 400mV to 3.75V in this application.

The unique input topology of the INA159 eliminates the input offset transition region typical of most rail-to-rail complementary stage operational amplifiers. This allows the INA159 to provide superior glitch- and transition-free performance over the entire common-mode range.

Good layout practice includes the use of a 0.1μF bypass capacitor placed closely across the supply pins.

## COMMON-MODE RANGE

The common-mode range of the INA159 is a function of supply voltage and reference. Where both pins, REF1 and REF2, are connected together:

$$V_{CM+} = (V+) + 5[(V+) - V_{REF}] \quad (1)$$

$$V_{CM-} = (V-) - 5[V_{REF} - (V-)] \quad (2)$$

Where one REF pin is connected to the reference, and the other pin grounded (1/2 reference connection):

$$V_{CM+} = (V+) + 5[(V+) - (0.5V_{REF})] \quad (3)$$

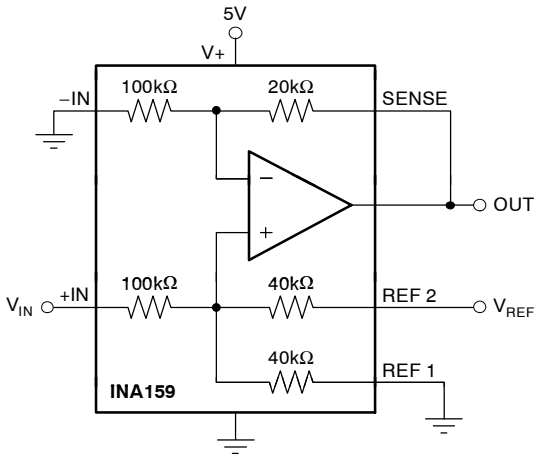
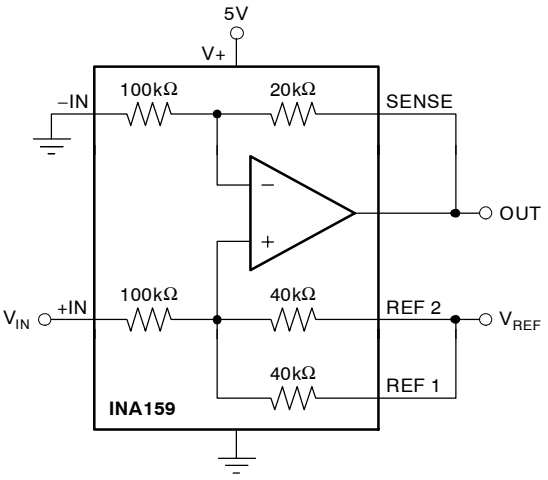
$$V_{CM-} = (V-) - 5[(0.5V_{REF}) - (V-)] \quad (4)$$

Some typical values are shown in Table 1.

**Table 1. Common-Mode Range For Various Supply and Reference Voltages**

| REF 1 and REF 2 Connected Together | | | | |
|---|---|---|---|---|
| **V+** | **V–** | **$V_{REF}$** | **$V_{CM+}$** | **$V_{CM-}$** |
| 5 | 0 | 3 | 15 | –15 |
| 5 | 0 | 2.5 | 17.5 | –12.5 |
| 5 | 0 | 1.25 | 23.75 | –6.25 |
| **1/2 Reference Connection** | | | | |
| **V+** | **V–** | **$V_{REF}$** | **$V_{CM+}$** | **$V_{CM-}$** |
| 5 | 0 | 5 | 17.5 | –12.5 |
| 5 | 0 | 4.096 | 19.76 | –10.24 |
| 5 | 0 | 2.5 | 23.75 | –6.25 |
| 3.3 | 0 | 3.3 | 11.55 | –8.25 |
| 3.3 | 0 | 2.5 | 13.55 | –6.25 |
| 3.3 | 0 | 1.25 | 16.675 | –3.125 |

**Table 2. Input and Output Relationships for Various Reference and Connection Combinations**

| $V_{REF}$ (V) | REF CONNECTION | $V_{OUT}$ for $V_{IN}$ = 0 (V) | LINEAR $V_{IN}$ RANGE (V) | USEFUL $V_{OUT}$ SWING (V) |
|---|---|---|---|---|
| 5 |  | 2.5 | +10<br>0<br>–10 | 4.5<br>(±2V swing)<br>0.5 |
| 4.096 | | 2.048 | +10<br>0<br>–10 | 4.048<br>(±2V swing)<br>0.048 |
| 3.3 | | 1.65 | +10<br>0<br>–7.885 | 3.65<br>(–1.577V, +2V swing)<br>0.048 |
| 2.5 | | 1.25 | +10 (also +5)<br>0<br>–6 (also –5) | 3.25<br>(–1.2V, +2V swing)<br>0.048 |
| 1.8 | | 0.9 | +10<br>0<br>–4.26 | 2.9<br>(–0.852V, +2V swing)<br>0.048 |
| 2.5 |  | 2.5 | +10<br>0<br>–10 | 4.5<br>(±2V swing)<br>0.5 |
| 1.8 | | 1.8 | +10<br>0<br>–8.76 | 3.8<br>(–1.752V, +2V swing)<br>0.048 |
| 1.2 | | 1.2 | +10<br>0<br>–5.76 | 3.2<br>(–1.15V, +2V swing)<br>0.048 |

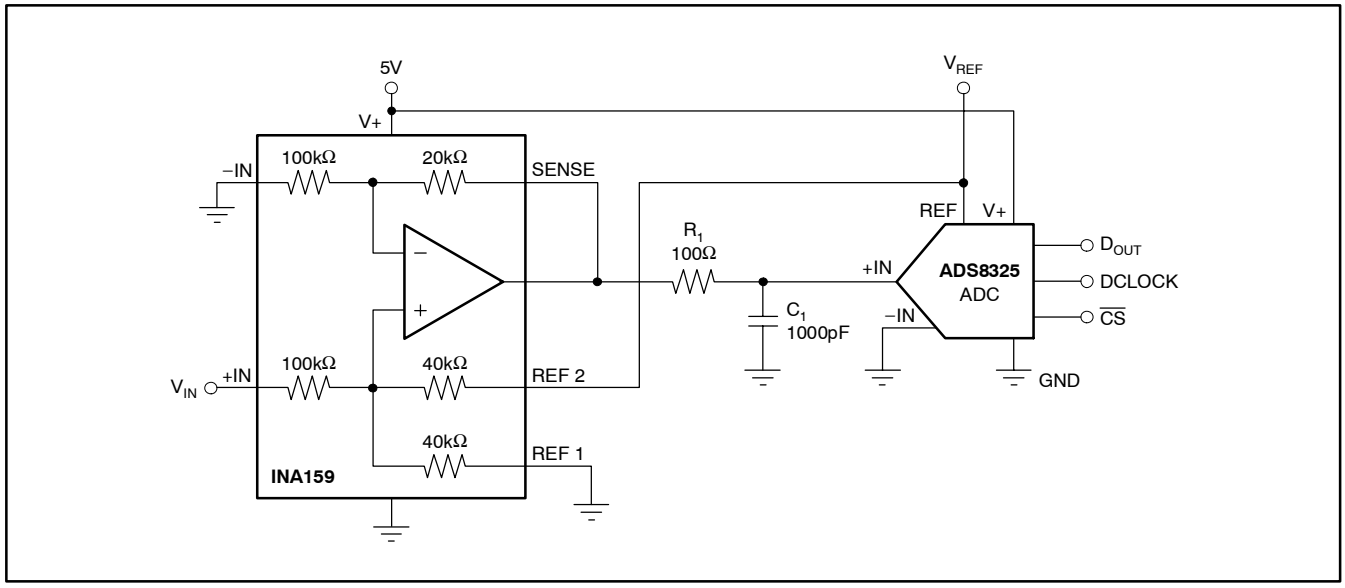



**Figure 3. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs**

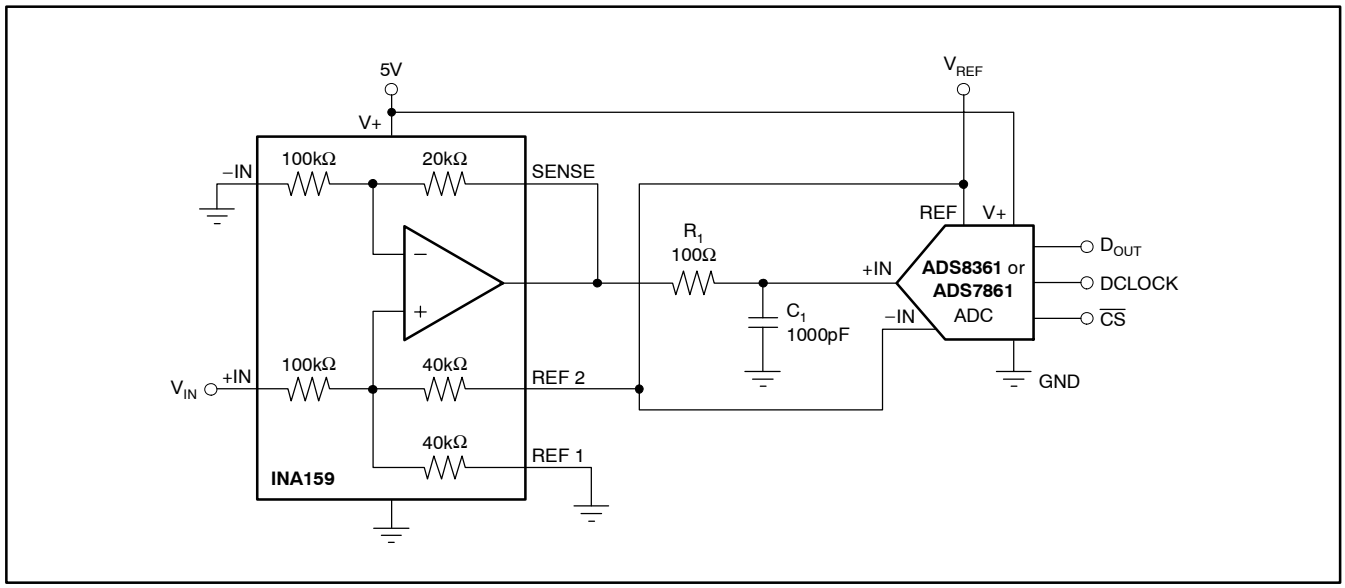
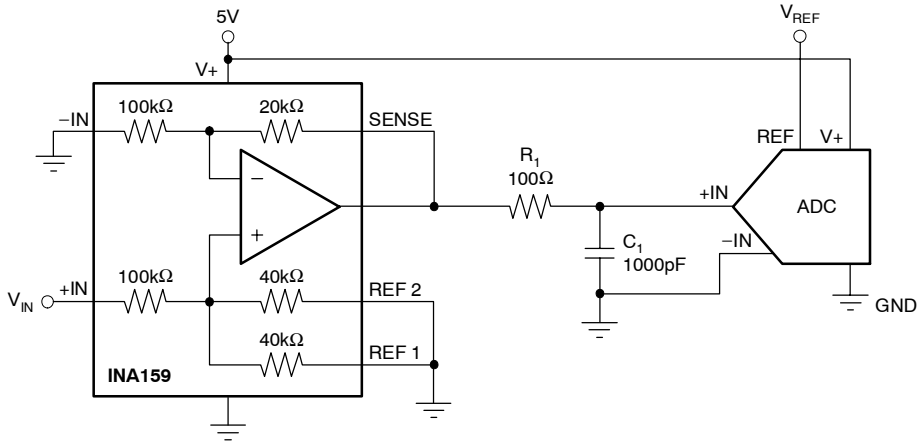
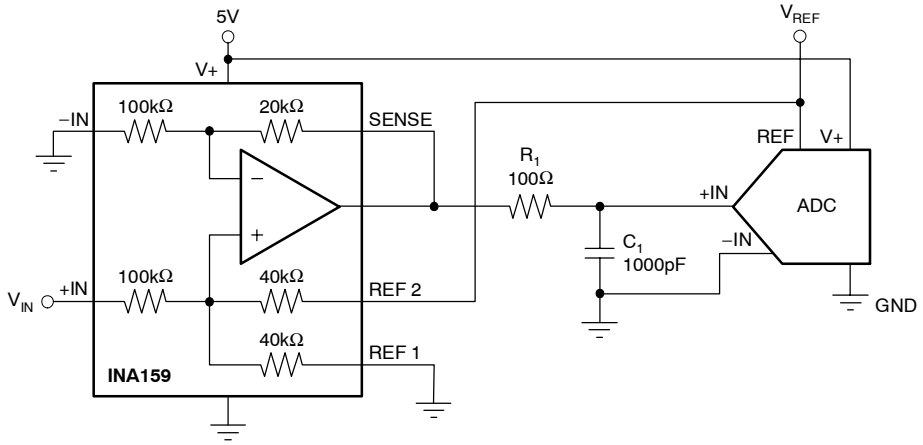


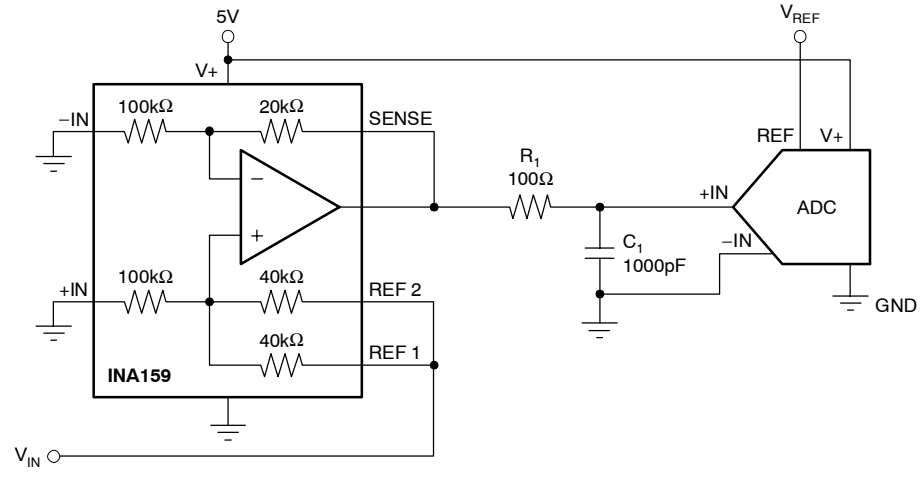

**Figure 4. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs with Pseudo-Differential Inputs (such as the ADS7861 and ADS8361)**




a) Unipolar, Noninverting, G = 0.2




b) Bipolar, Noninverting, G = 0.2




c) Unipolar, Unity Gain

**Figure 5. Basic INA159 Configurations**

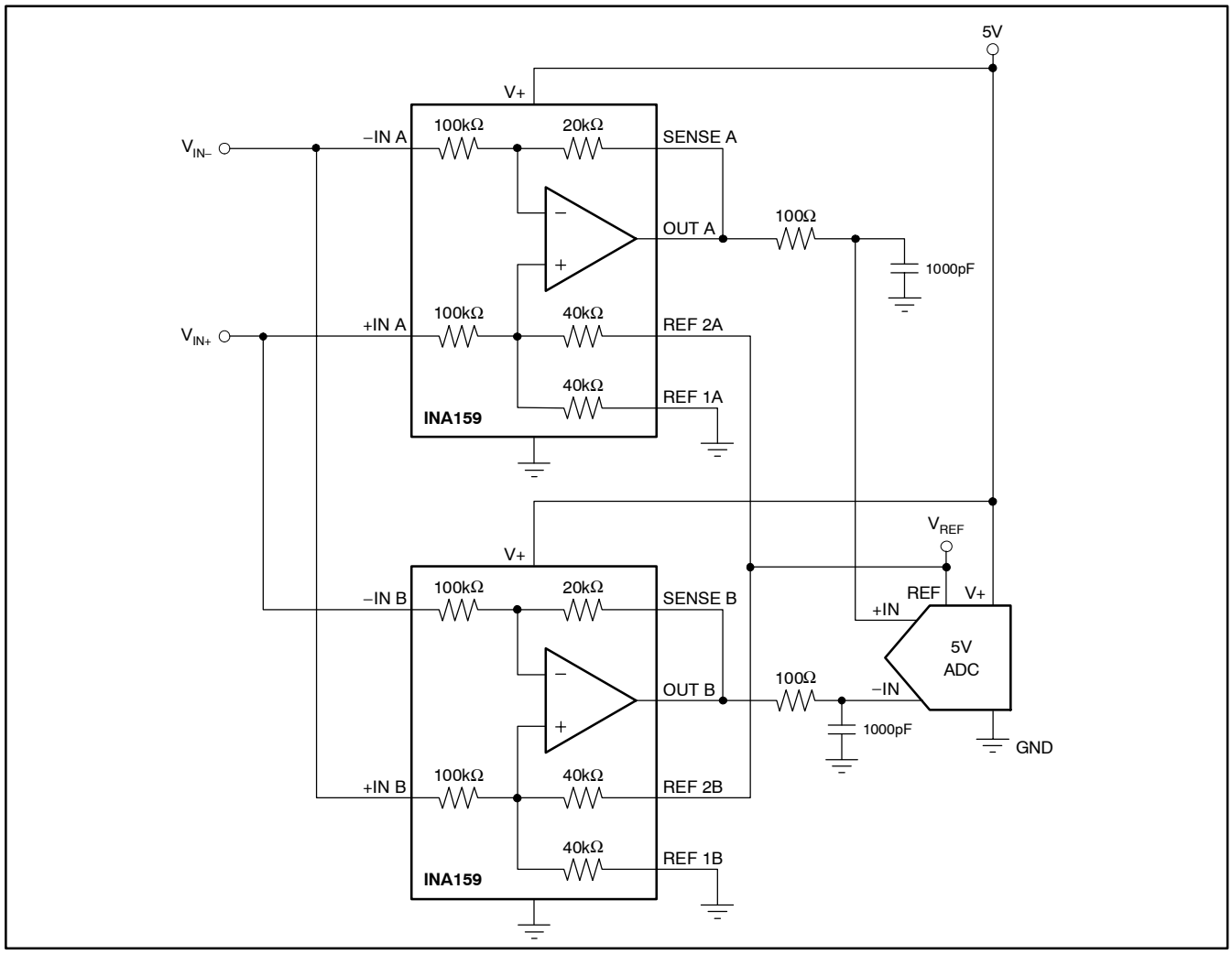



**Figure 6. Differential ADC Drive**

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/ Ball Finish | MSL Peak Temp (3) | Samples (Requires Login) |
|---|---|---|---|---|---|---|---|---|---|
| INA159AIDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | |
| INA159AIDGKRG4 | ACTIVE | VSSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | |
| INA159AIDGKT | ACTIVE | VSSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | |
| INA159AIDGKTG4 | ACTIVE | VSSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**OTHER QUALIFIED VERSIONS OF INA159 :**

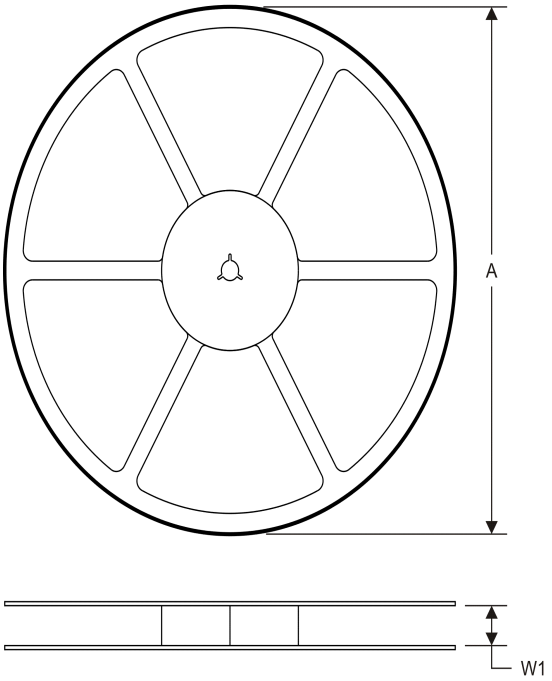
- Enhanced Product: INA159-EP

NOTE: Qualified Version Definitions:

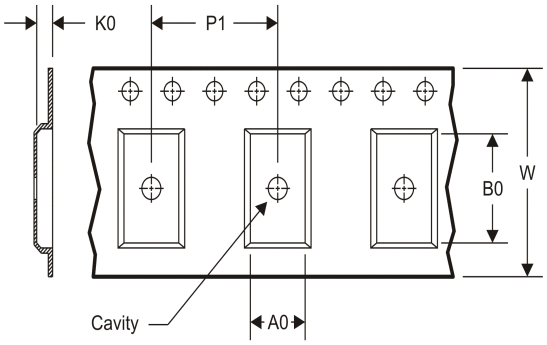
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**




**TAPE DIMENSIONS**



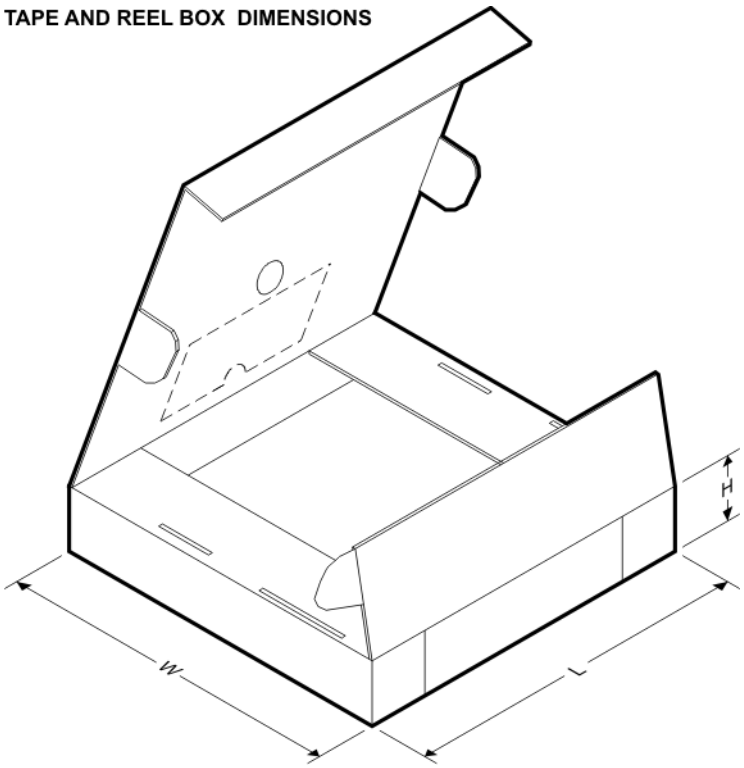

| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

**TAPE AND REEL INFORMATION**

*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA159AIDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA159AIDGKT | VSSOP | DGK | 8 | 250 | 180.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

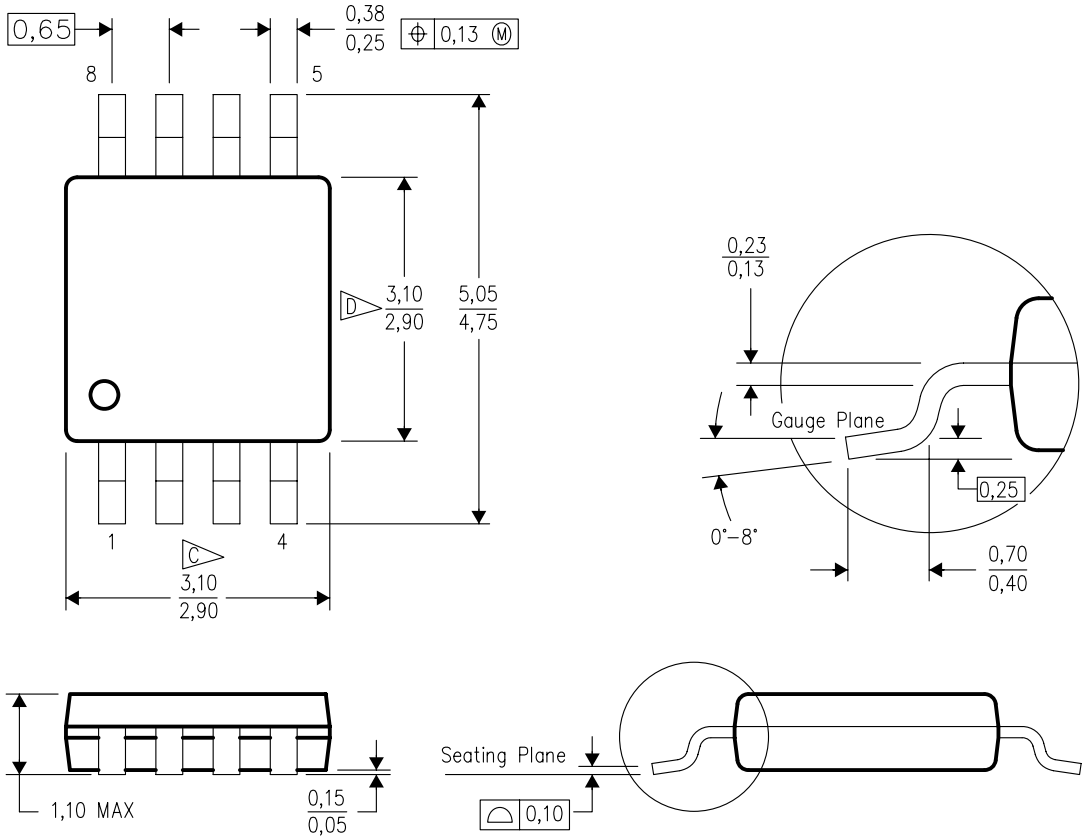
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA159AIDGKR | VSSOP | DGK | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| INA159AIDGKT | VSSOP | DGK | 8 | 250 | 210.0 | 185.0 | 35.0 |

DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE




4073329/E 05/06

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO–187 variation AA, except interlead flash.

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